

Fermilab Booster model calibration

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Model calibration using optimization (penalty) function:

$$F = \sum_{i,j} \left[\left(\frac{\partial x_i}{\partial \theta_j} \right)_m - \left(\frac{\partial x_i}{\partial \theta_j} \right)_t \right]^2 \frac{1}{\sigma_{ij}^2}$$

Measured response

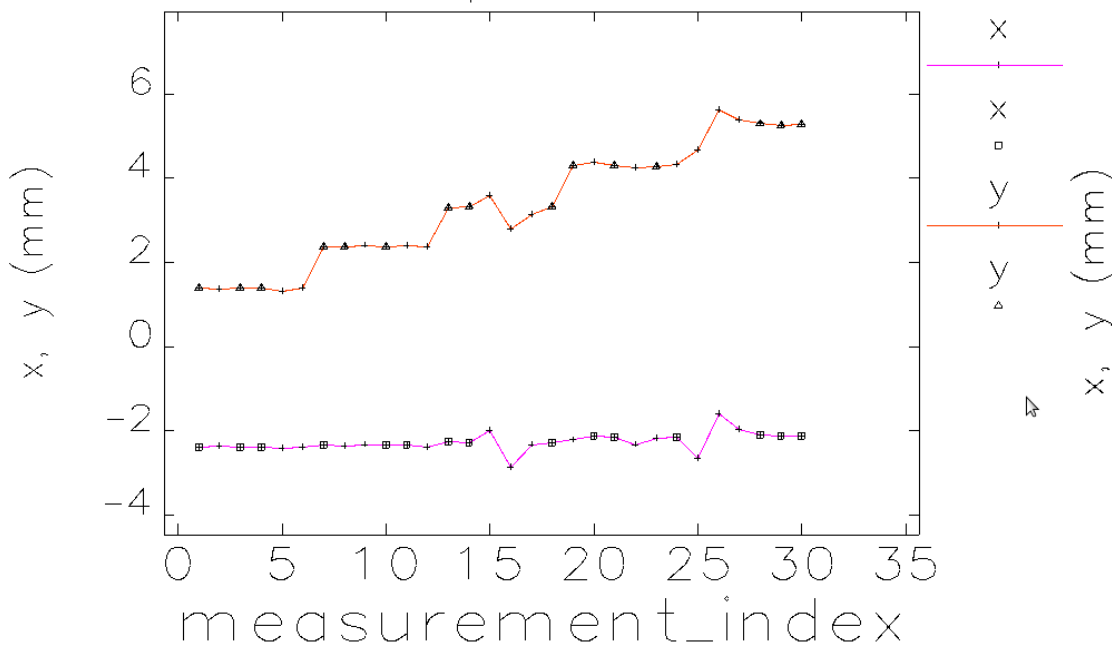
Model

Measurement accuracy

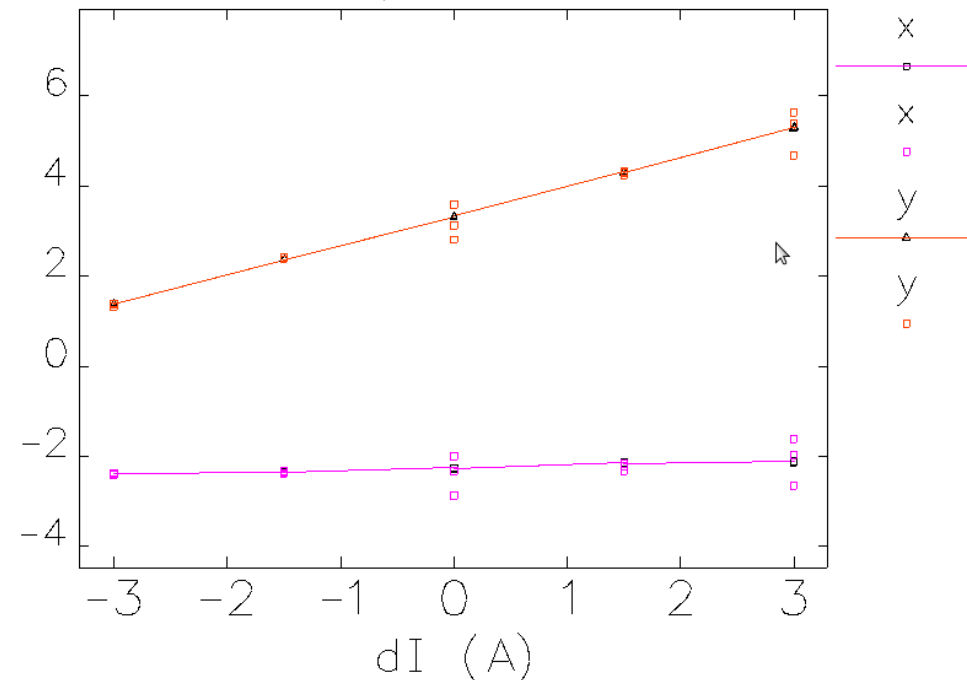
The objective is to find a set of hidden model parameters (focusing errors, BPM calibrations etc.) which minimizes F . SVD-based optimization is typically used.

Booster orbit response measurements:

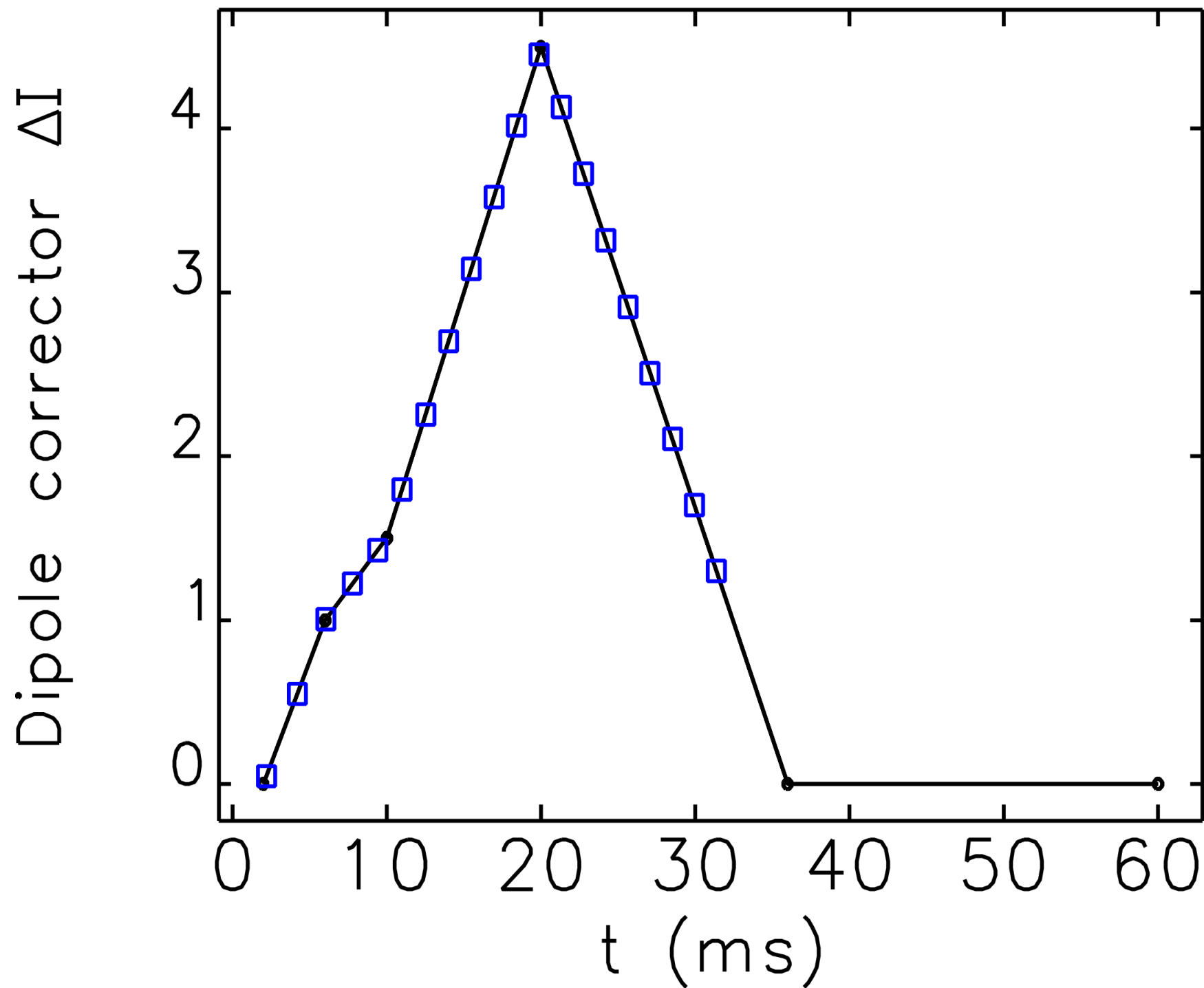
20L response to VL5



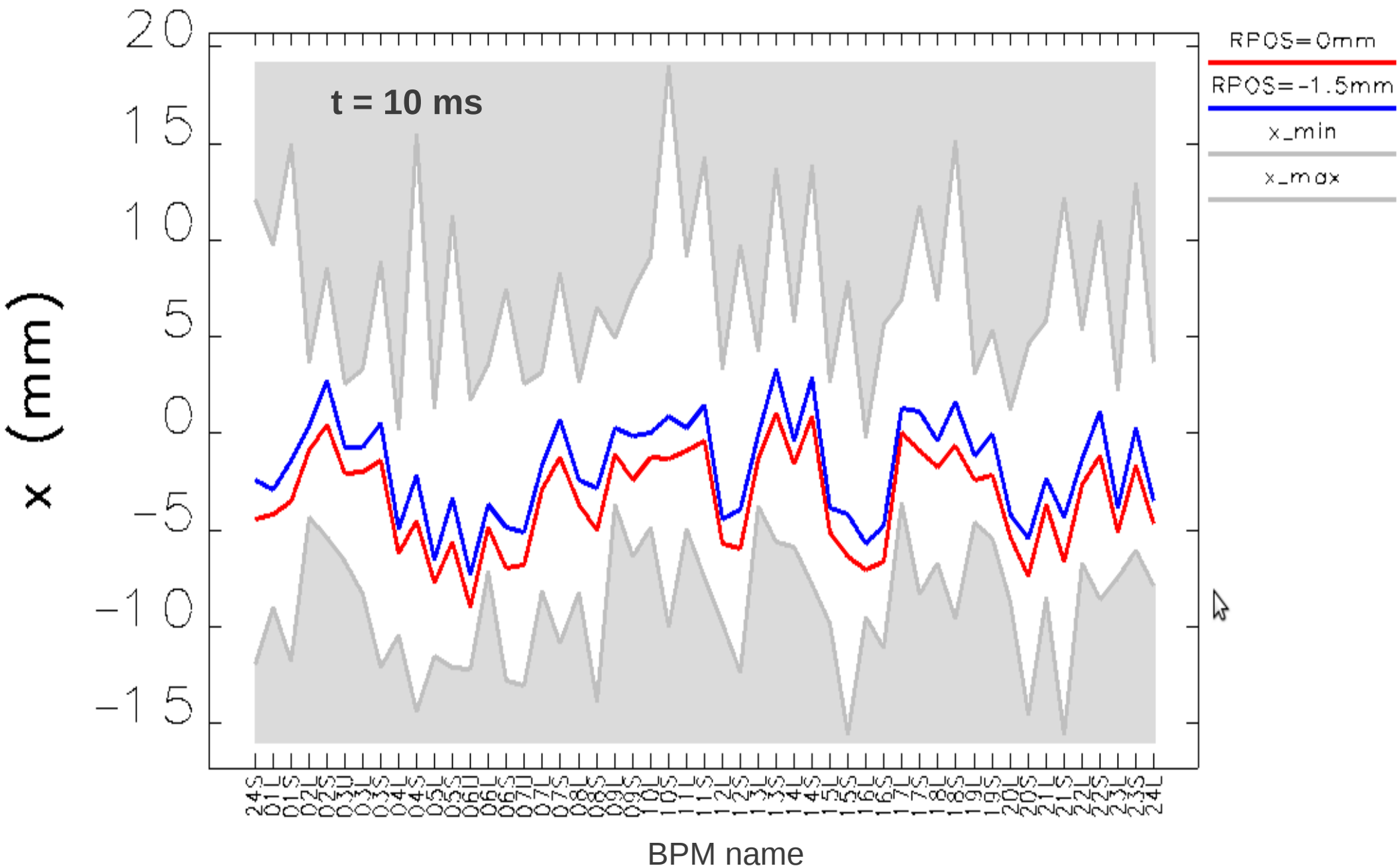
20L response to VL5



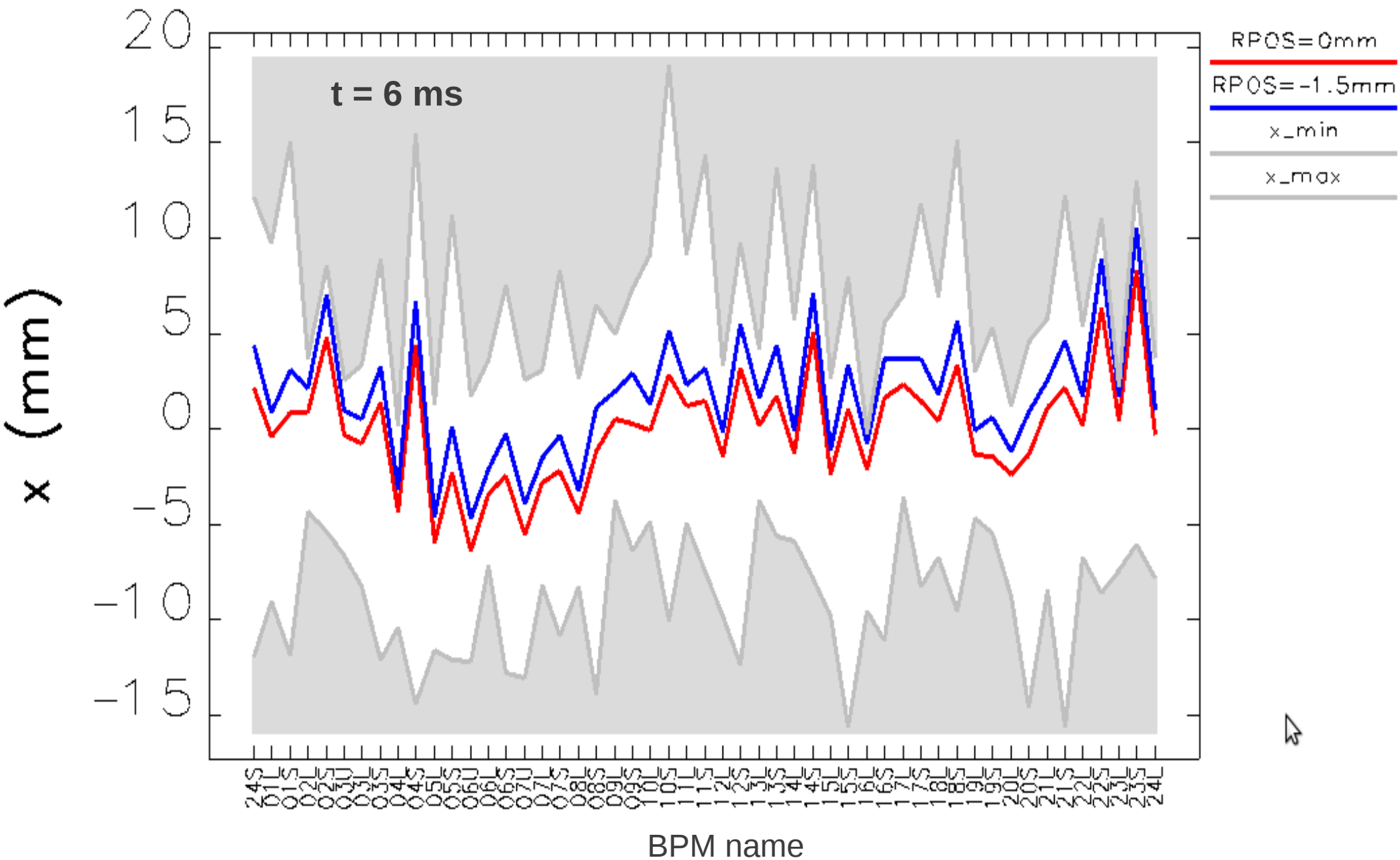
□ Orbit measurement



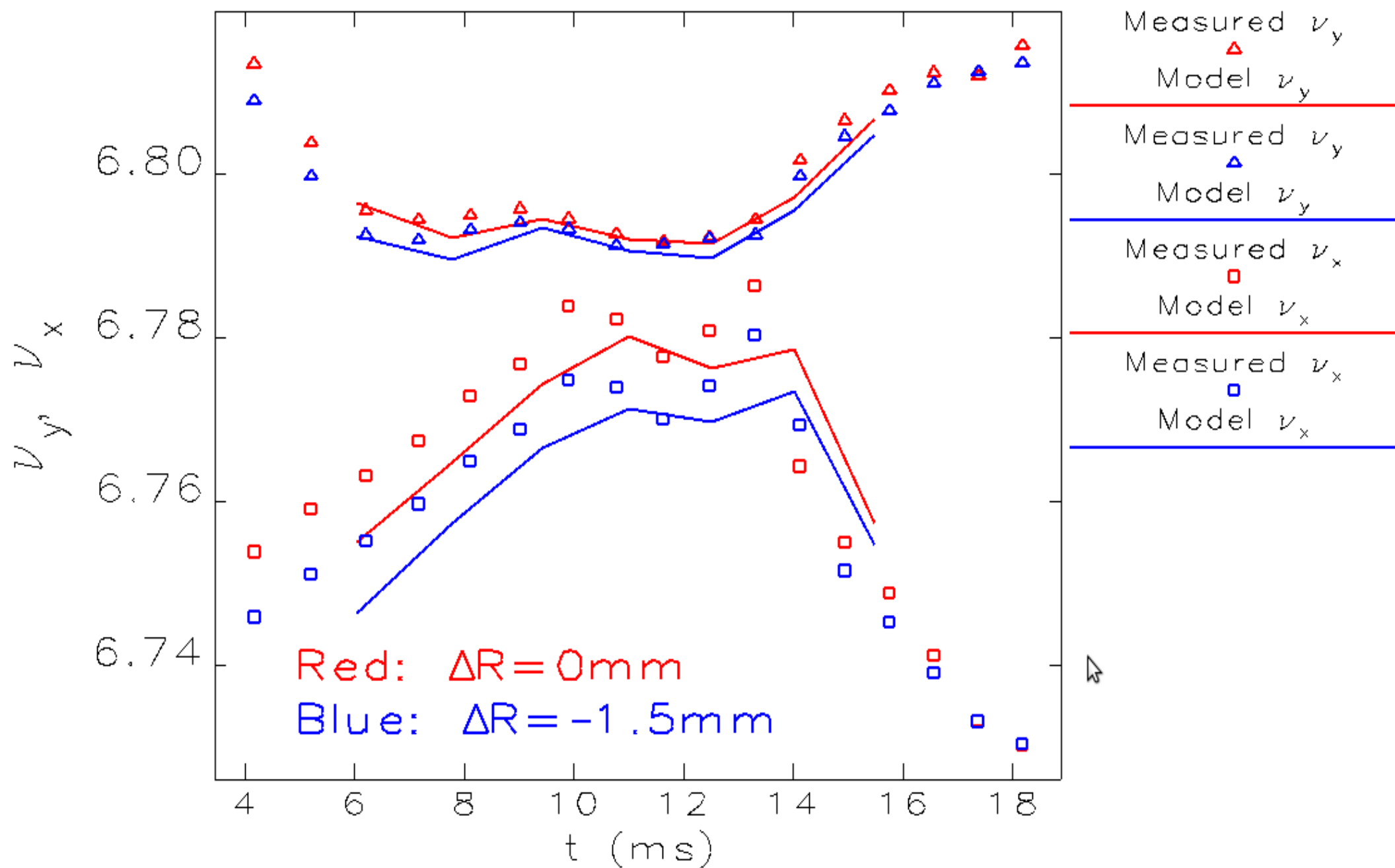
Orbit response matrix measured with different radial offset (RPOS) settings:



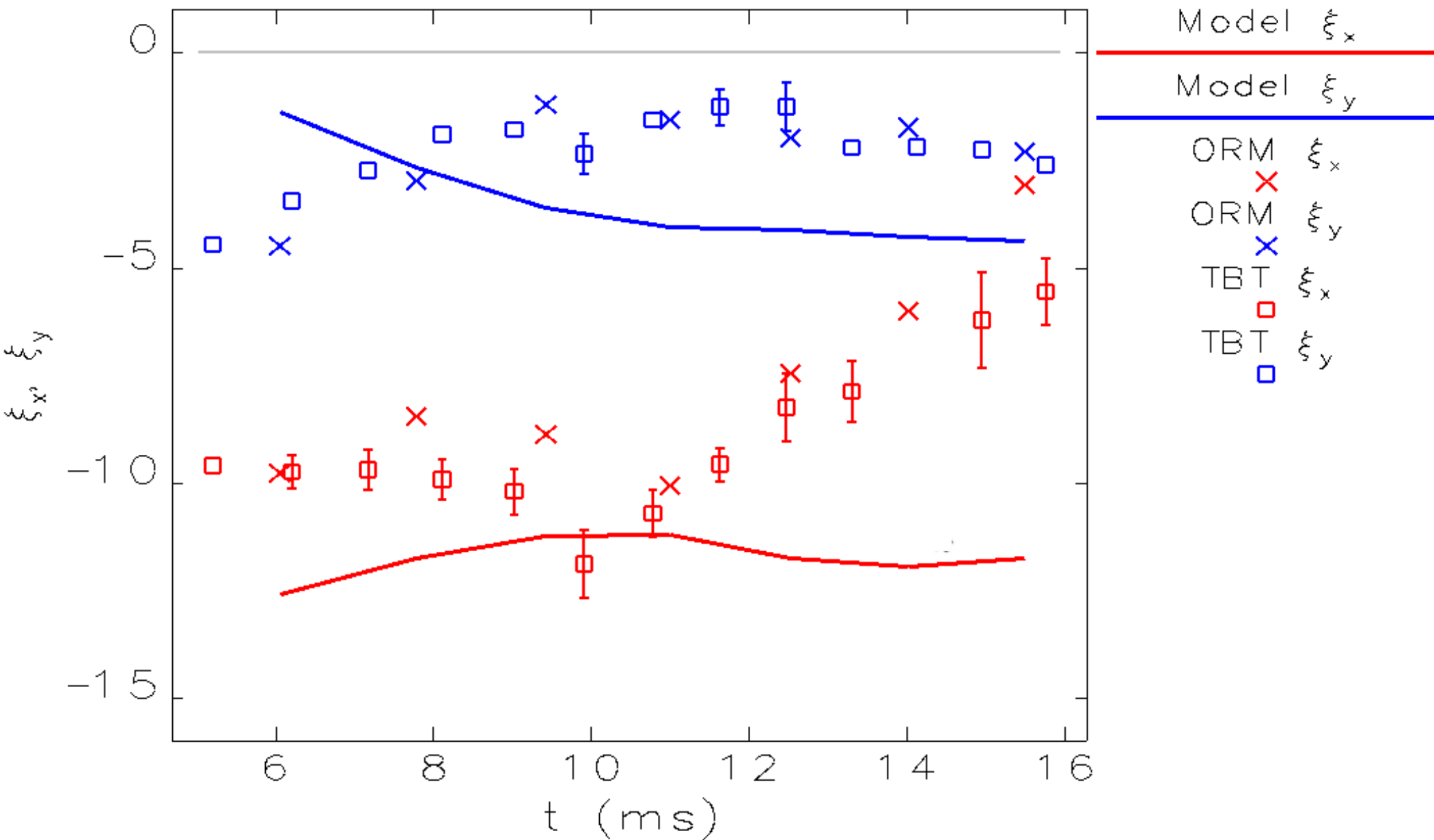
Orbit response matrix measured with different radial offset (RPOS) settings:



Orbit response matrix fitting with different radial offset (RPOS) settings:

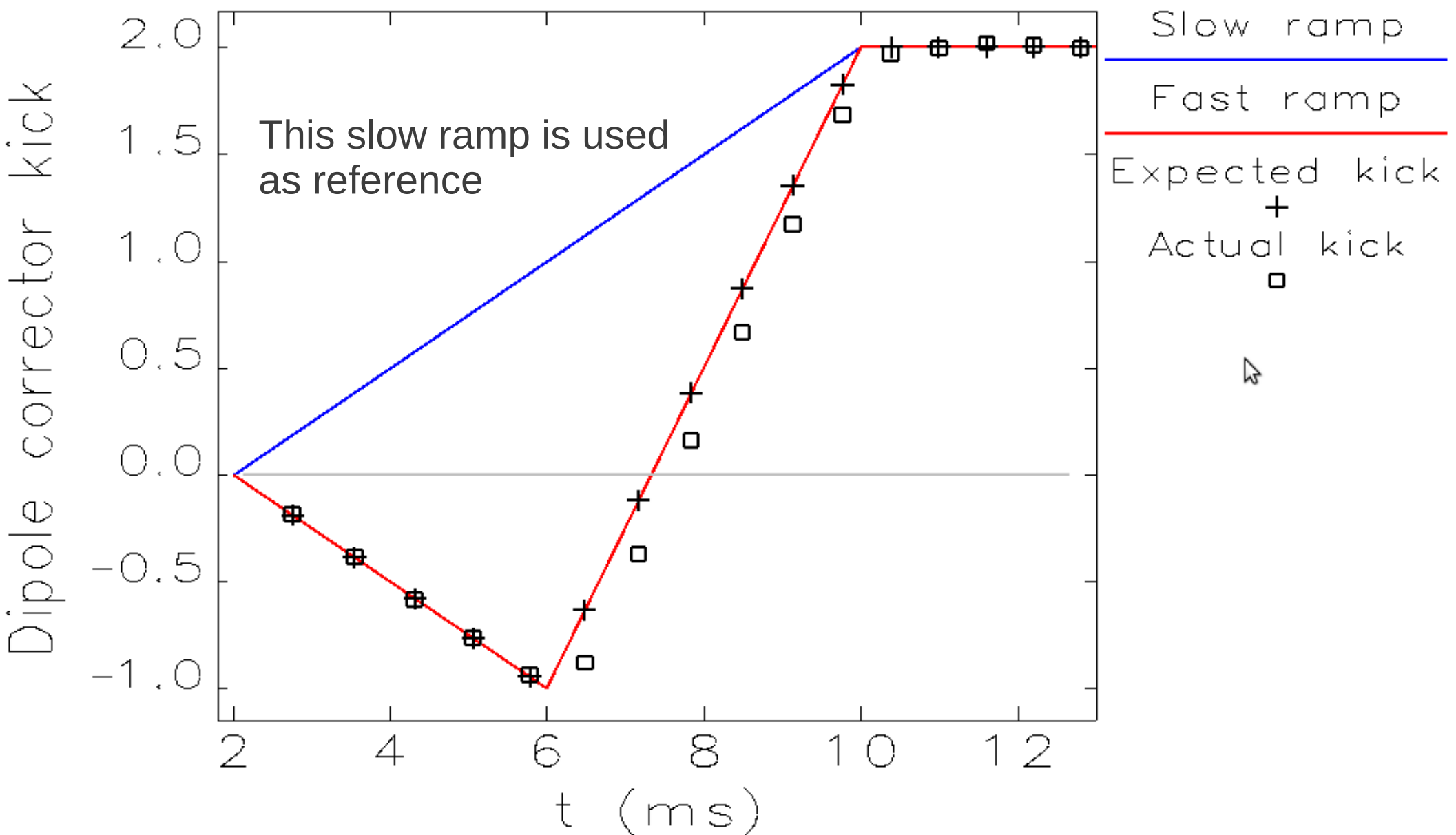


Chromaticity measured via turn-by-turn tunes and via ORM tunes:



=> Unknown sextupole errors and sextupole correctors have strengths of the same order of magnitude

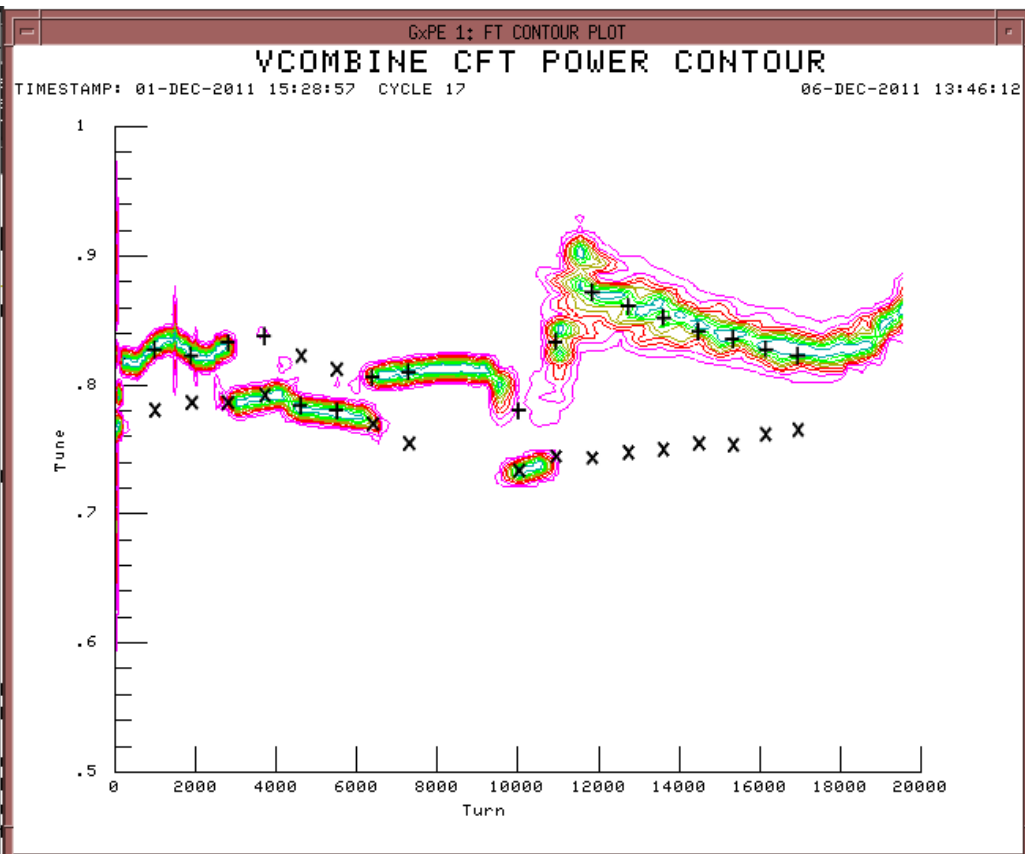
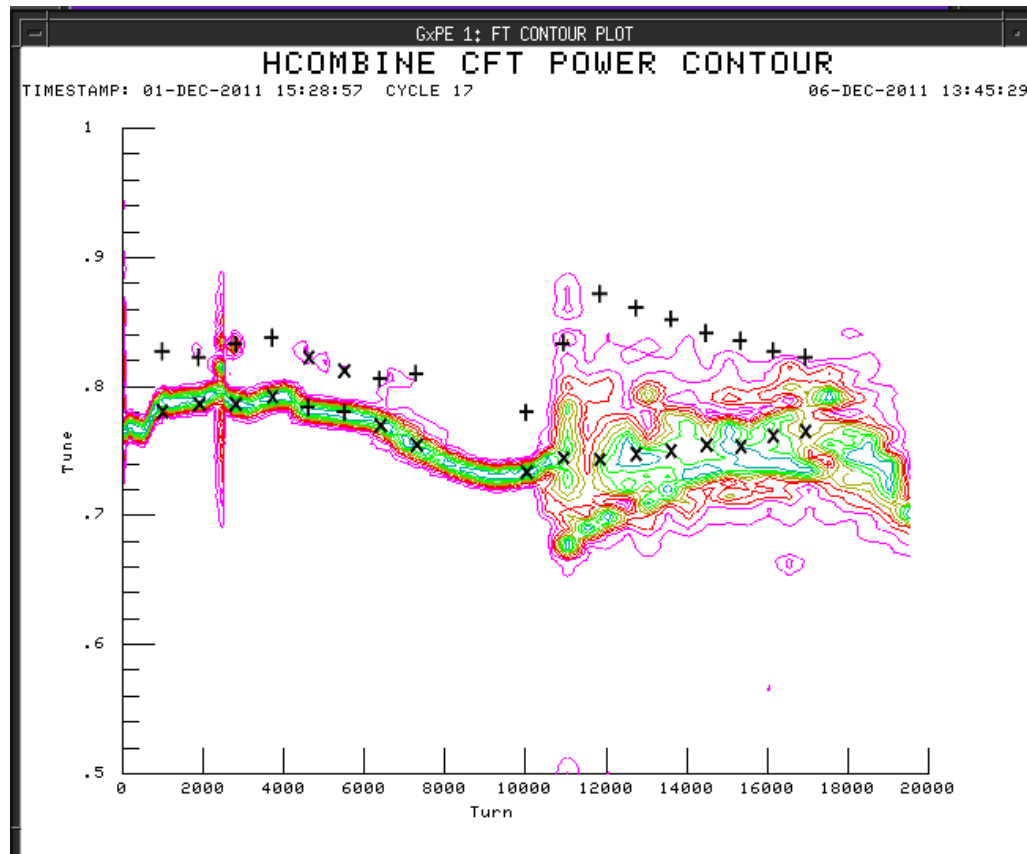
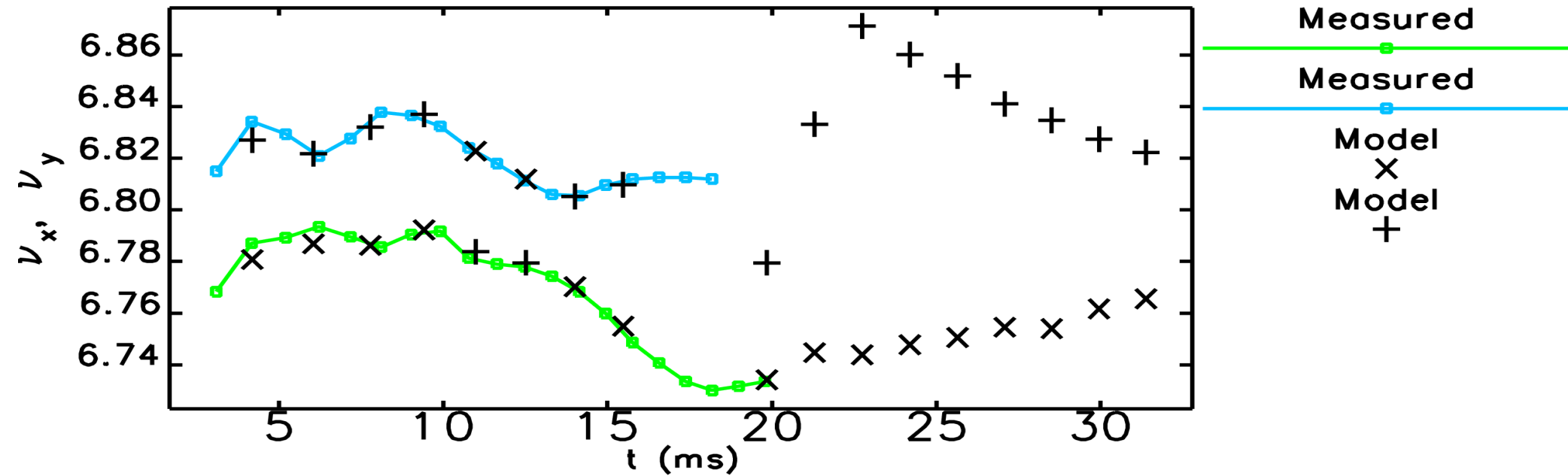
Orbit response-based measurement of field delay due to eddy-currents:



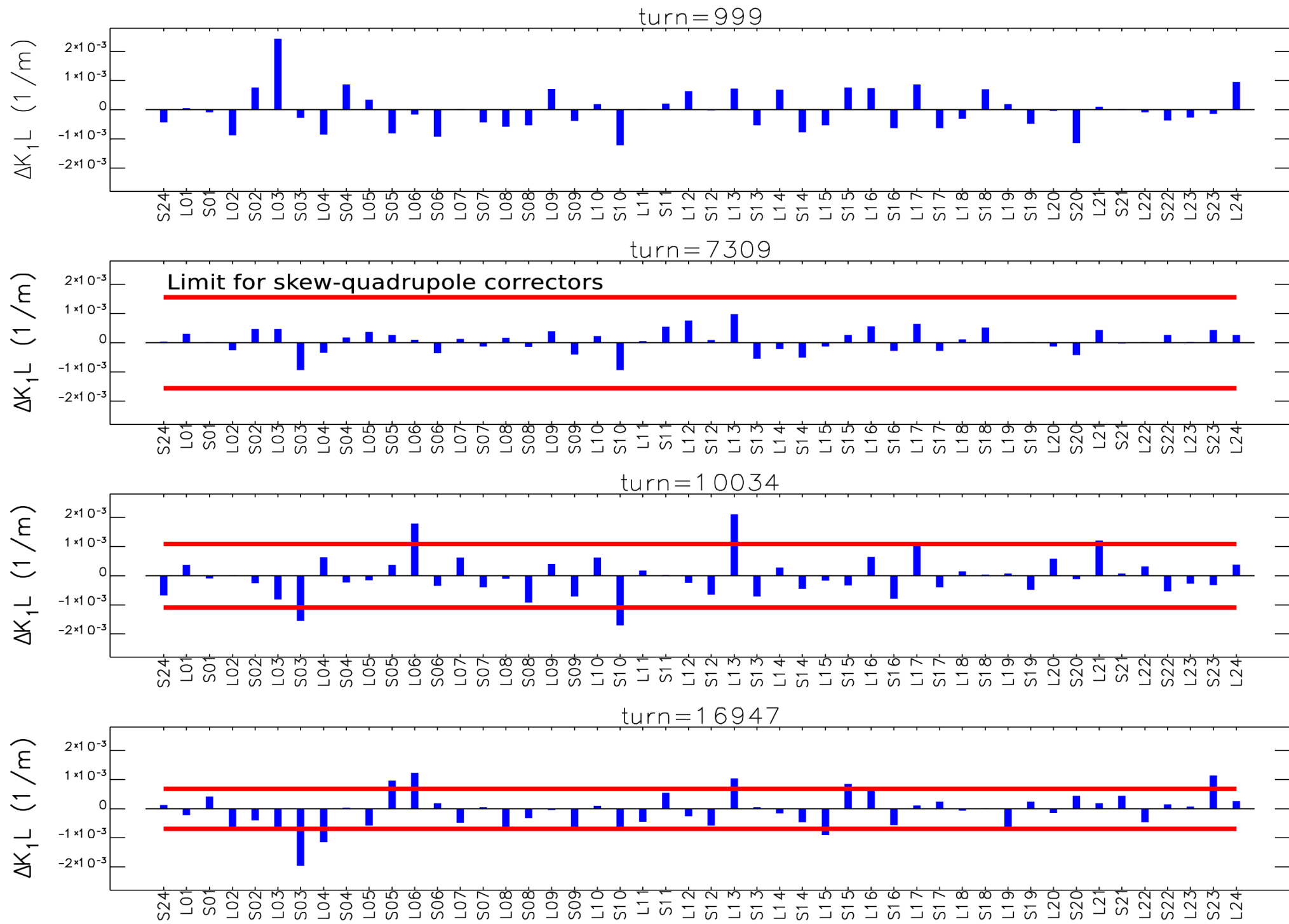
Conclusions:

- Booster optics is very well reproducible from pulse to pulse => accurate orbit and tune response measurements are possible
- Precise linear optical model of the Booster was obtained for the whole cycle
- The obtained model was successfully used to correct coupling in the Booster (before transition).
- Next steps: beta-beating correction, sextupole corrector calibrations, transverse impedances, GUI application to measure orbit response matrix in the Booster.

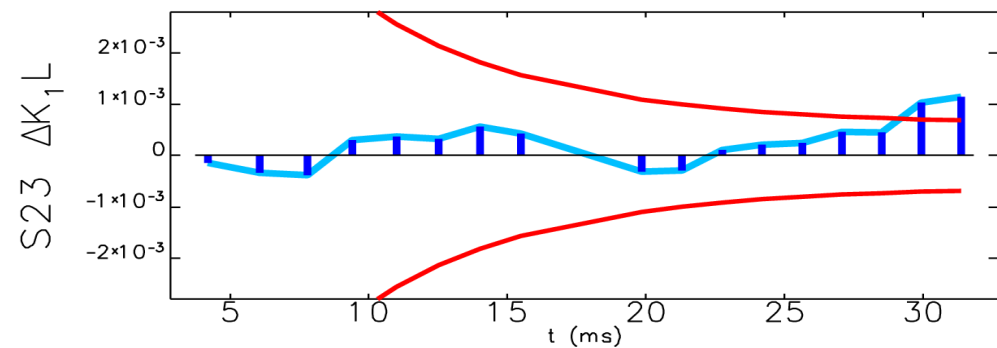
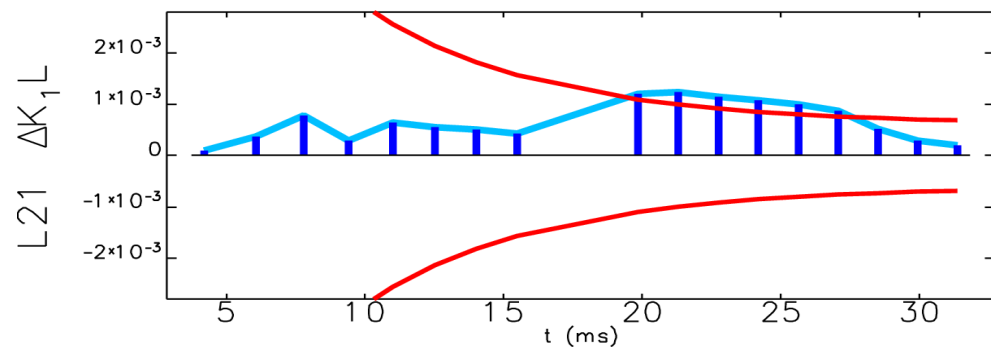
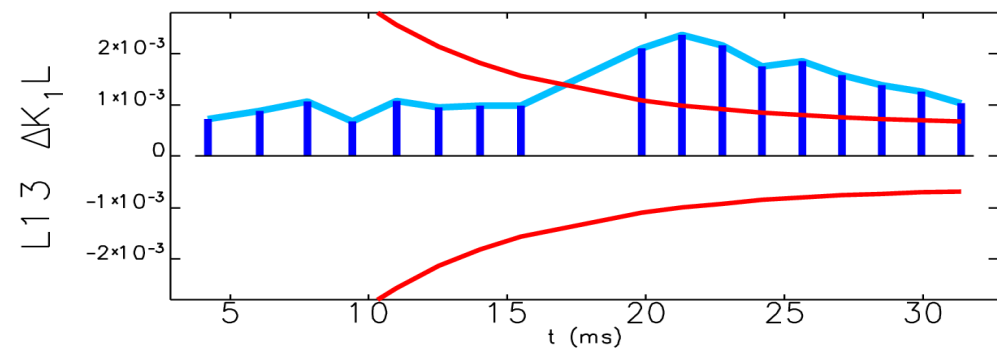
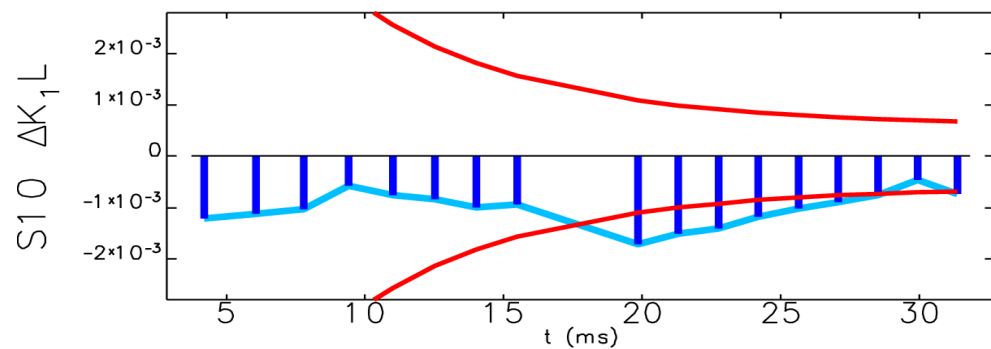
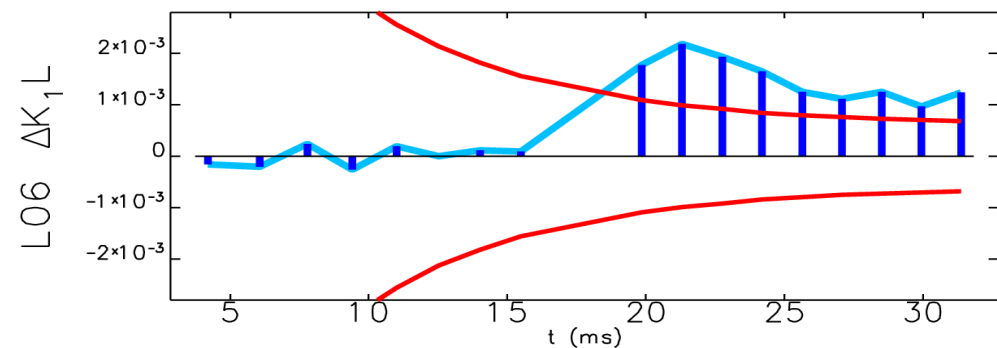
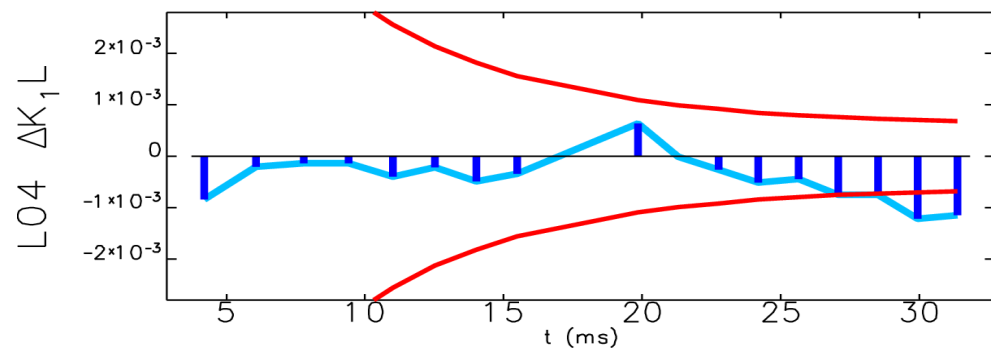
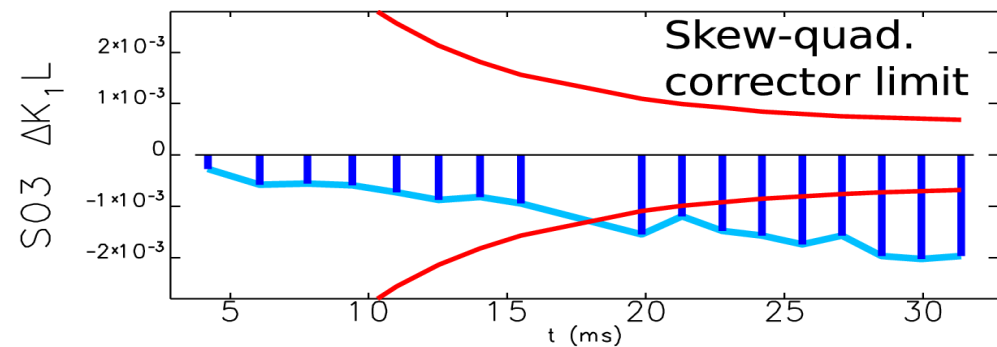
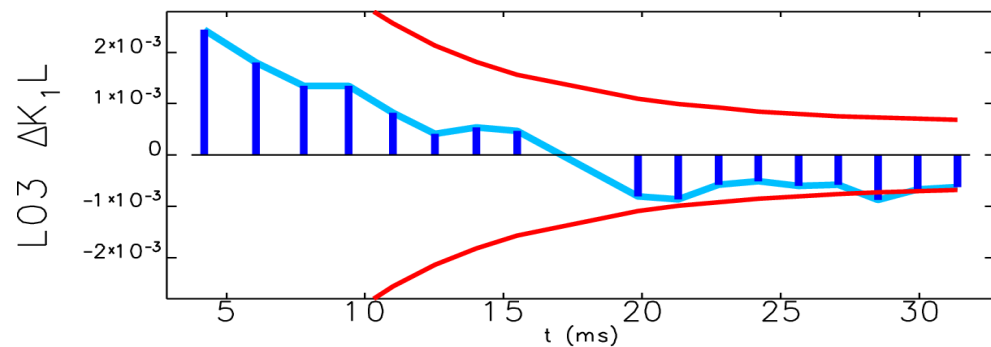
Tunes predicted by the calibrated model (tunes were not used in model calibration)



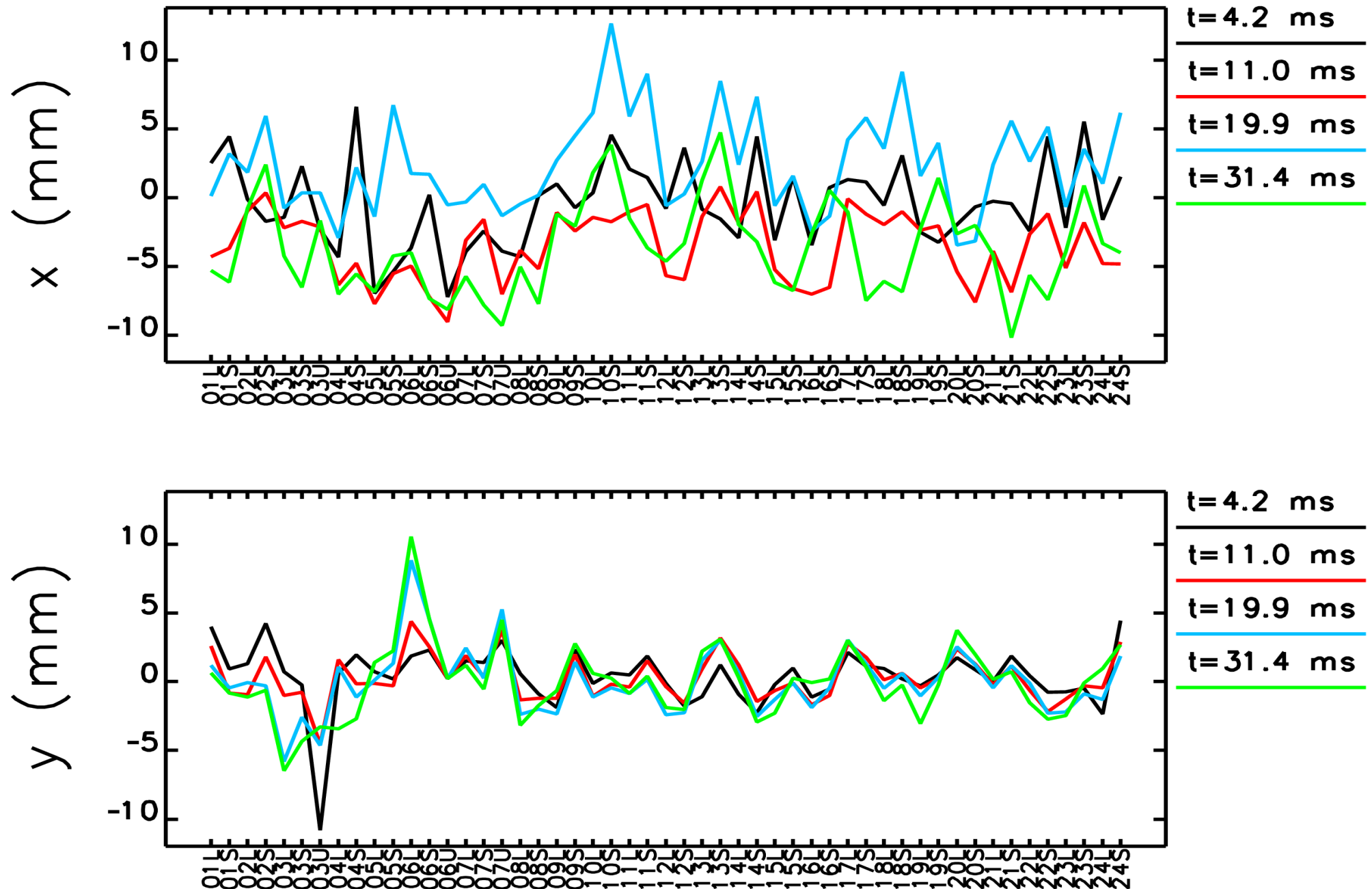
Skew-quadrupole errors (all focusing errors are located inside correctors)



Some large skew-quadrupole errors vs time:



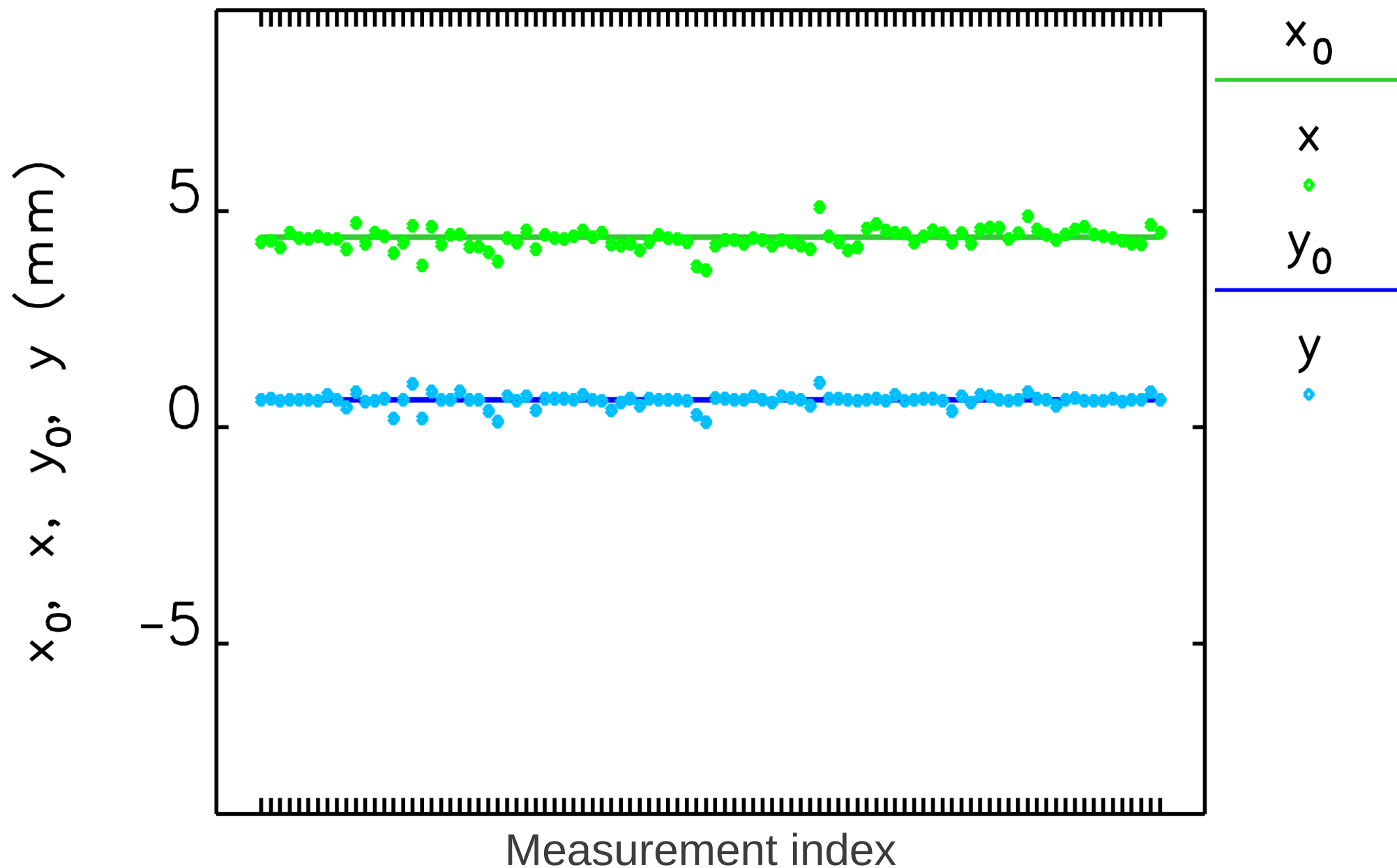
Orbit changes during acceleration – the probable source of dynamical focusing errors:



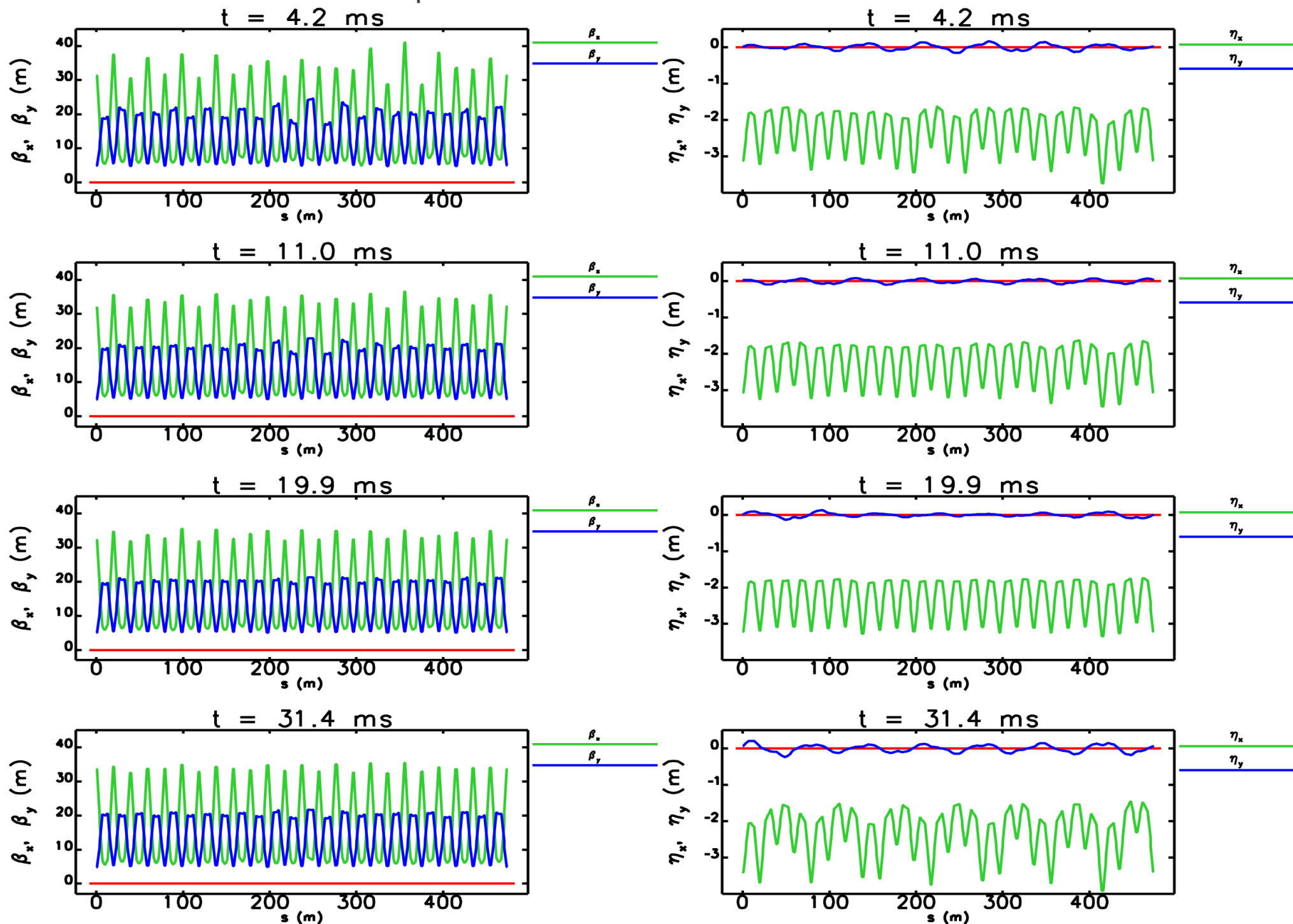
From pulse to pulse orbit position at all BPMs is reproduced with accuracy better than 1 mm

Orbit stability from pulse to pulse (t=6 ms):

04S BPM

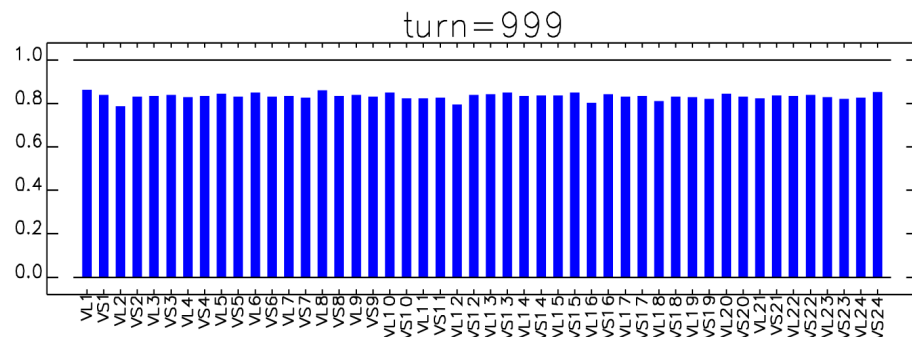


Model beta-function and dispersion function vs time:

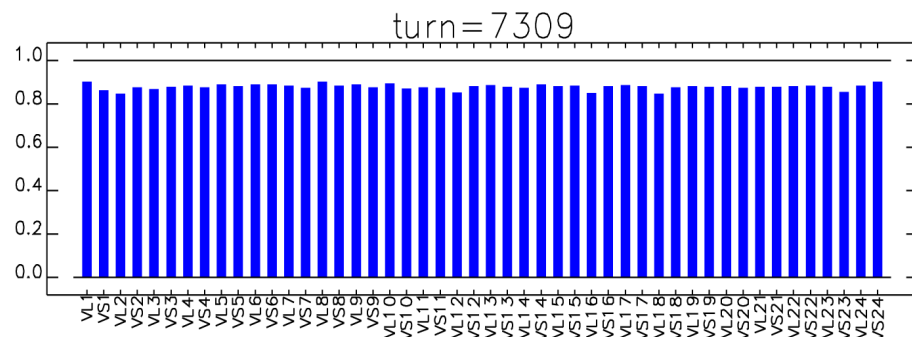


Corrector calibrations:

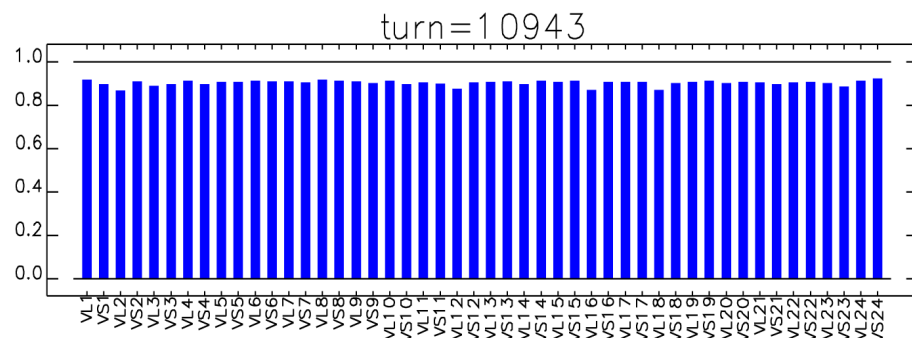
calibration



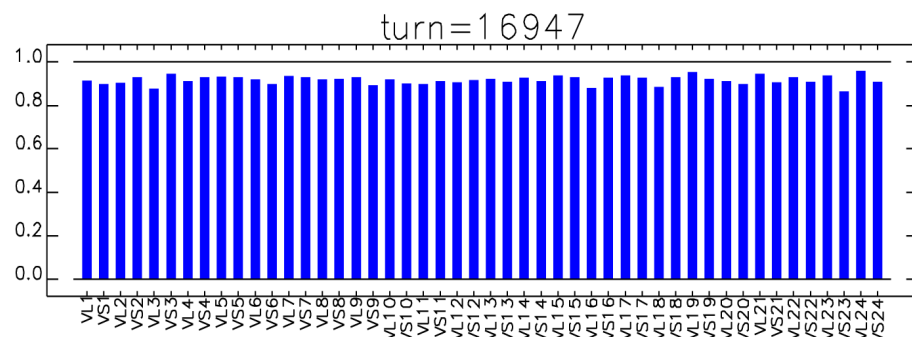
calibration



calibration

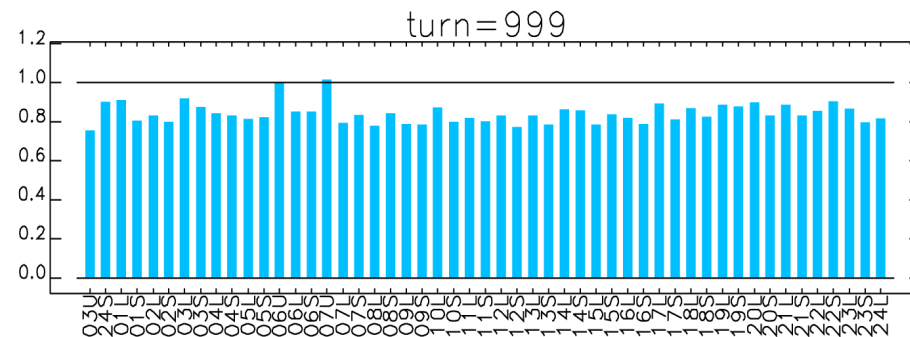


calibration

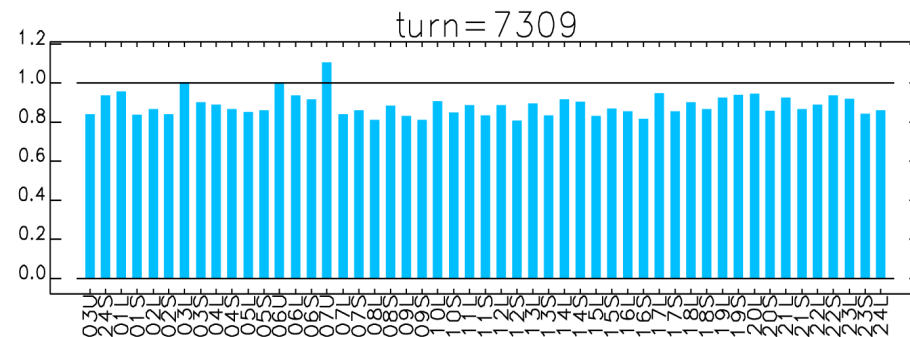


BPM gain factors:

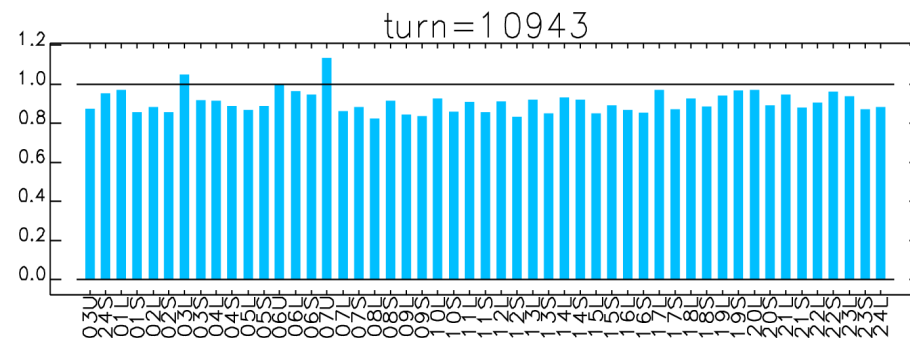
Y_GIAN



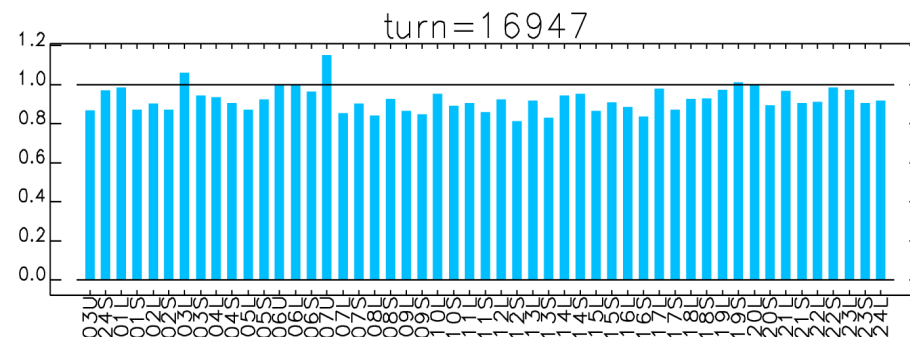
Y_GIAN



Y_GIAN

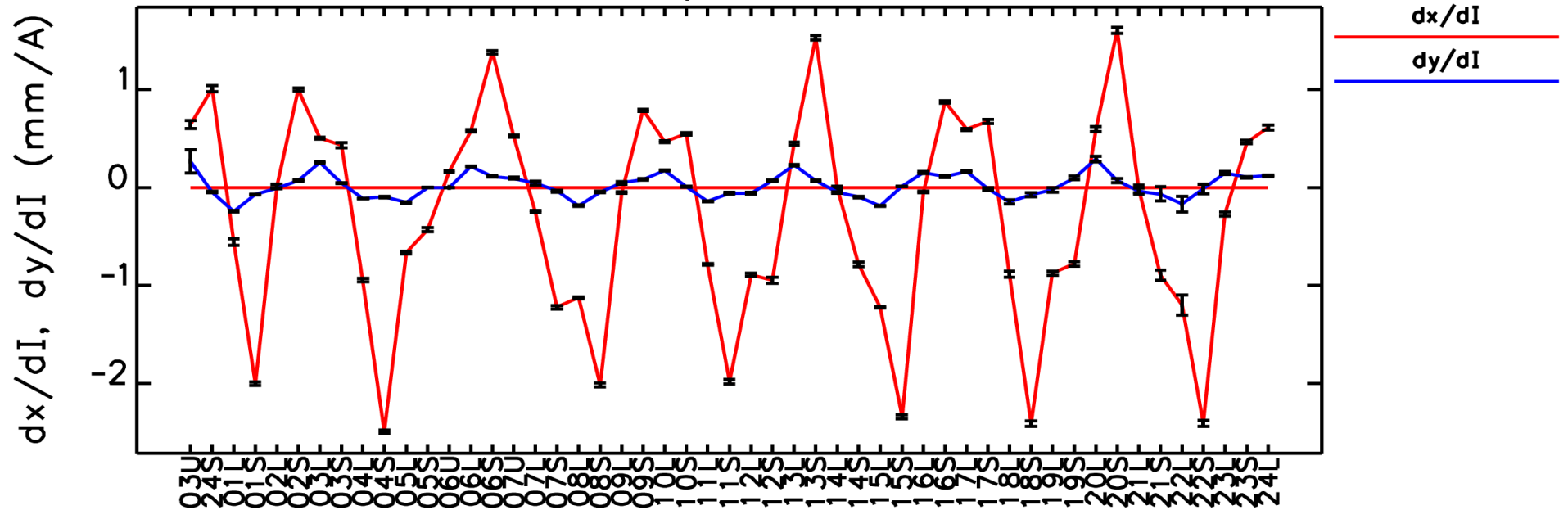


Y_GIAN



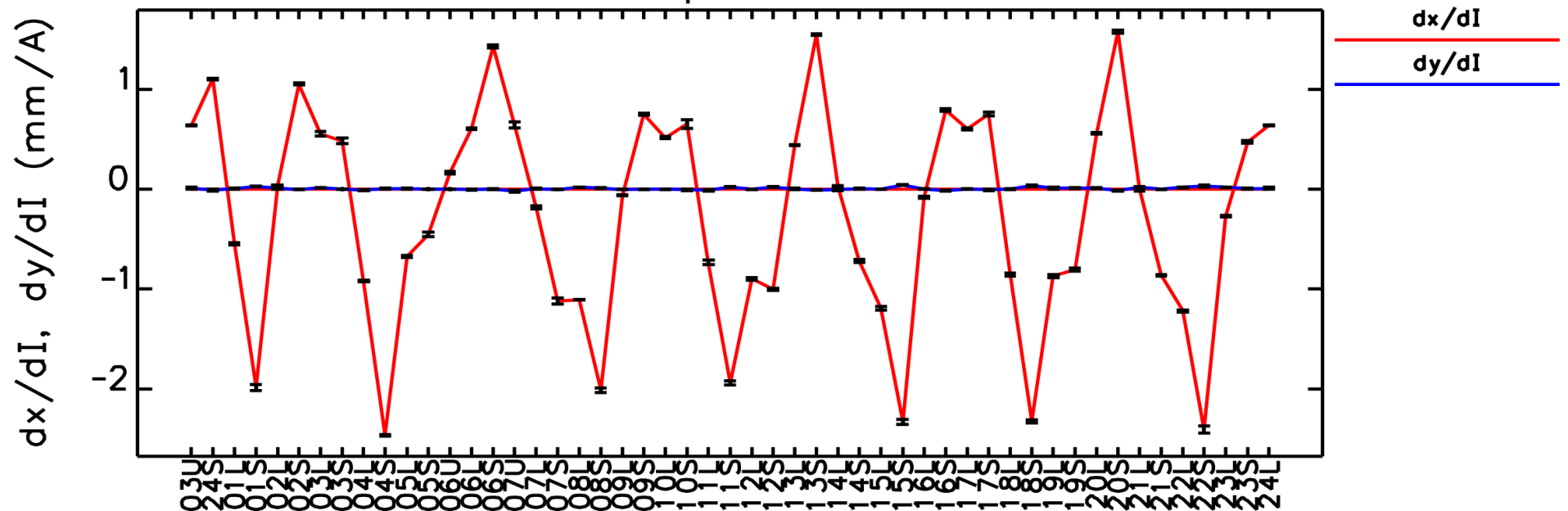
Before coupling correction:

Orbit response to HS1

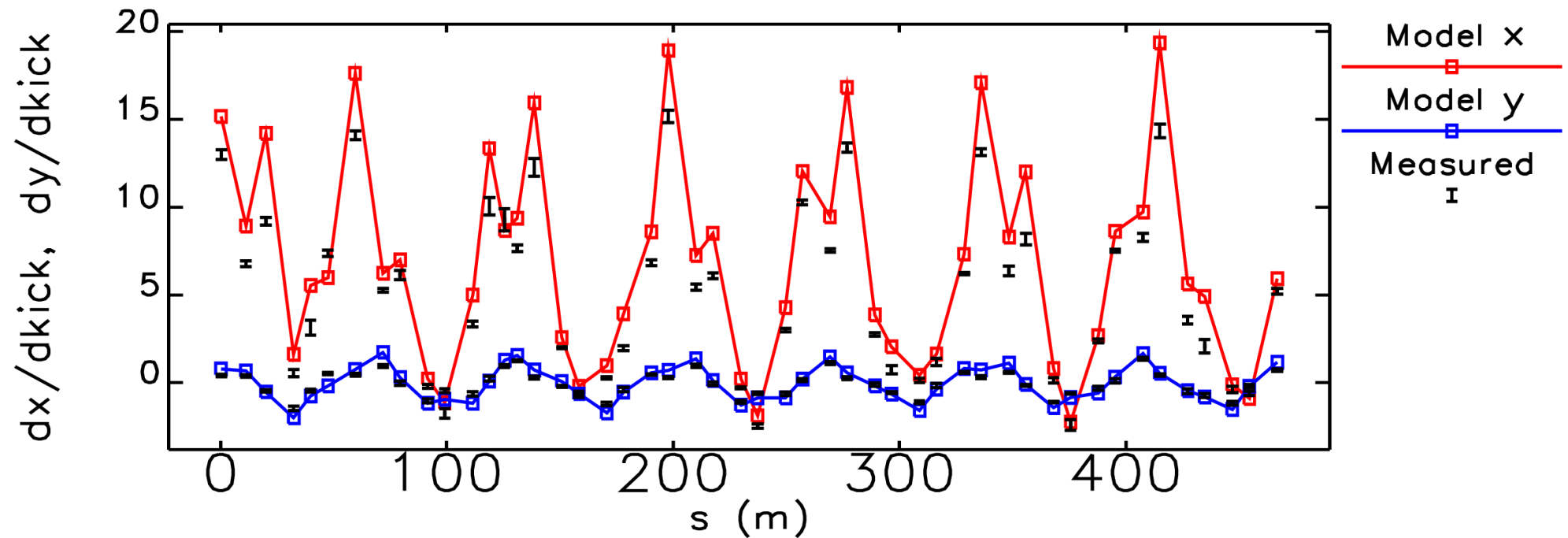


After coupling correction:

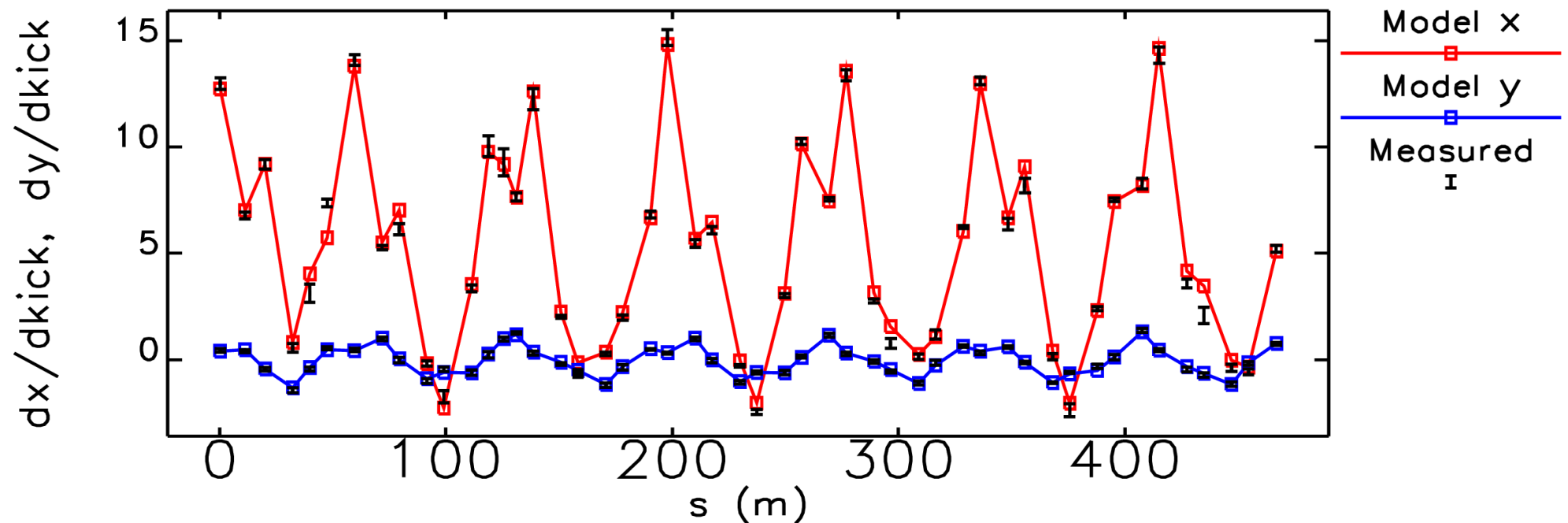
Orbit response to HS1



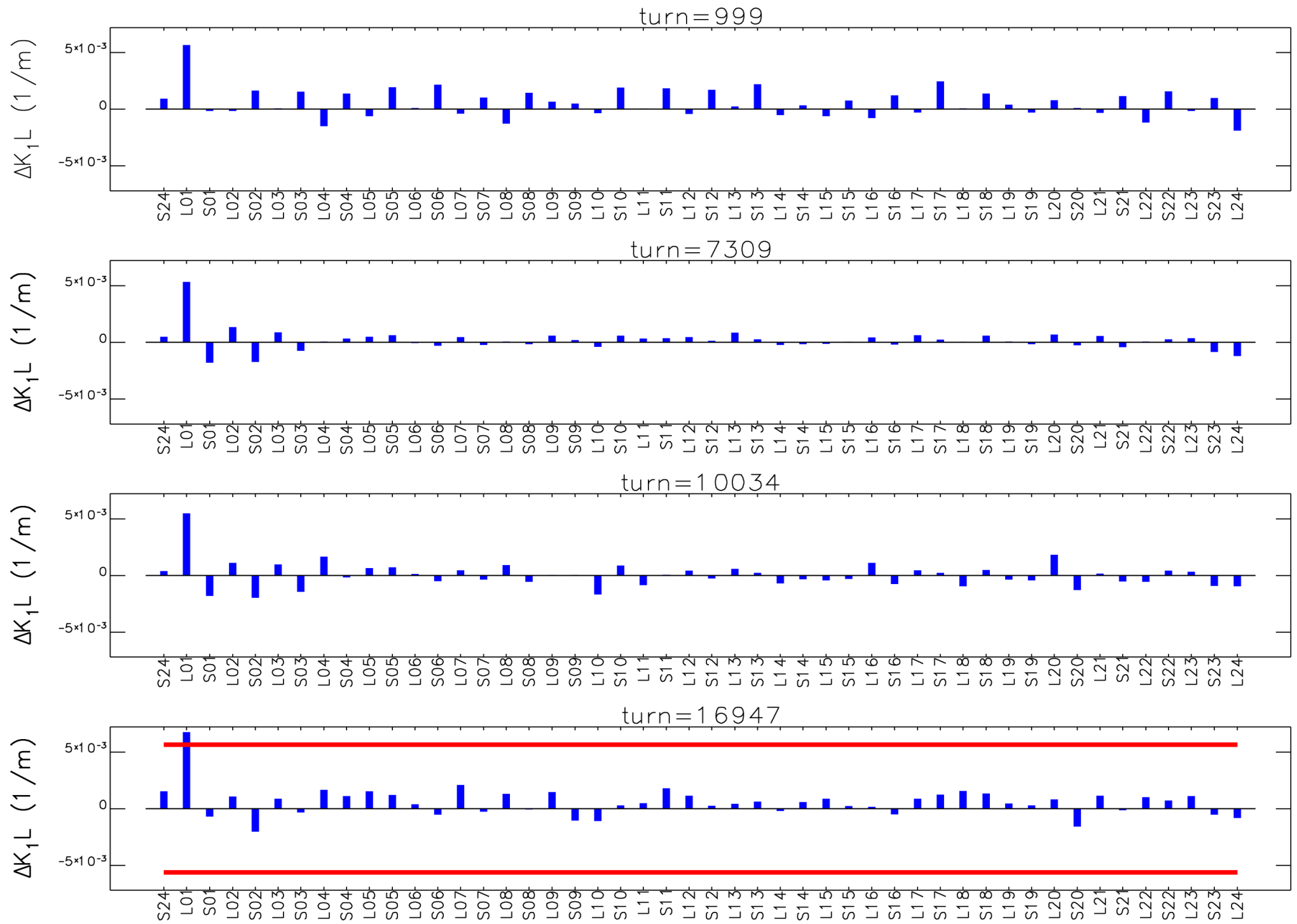
Before model calibration:



After model calibration:



Quadrupole errors (all focusing errors are located inside correctors)



Some large quadrupole errors vs time:

